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Solar Water Pumping System with Improved Efficiency and Less Maintenance

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Abstract: Solar systems are becoming increasingly prevalent in distribution and generating system. This is because of its large availability. Even though there is a large availability, it is not commonly used because large area with huge installation cost as well as maintenance cost is required. One of the major field in which solar energy used is water pumping for small scale irrigation. This paper is aimed to introduce Ćuk converter as well as impedance source inverter in pumping system along with photovoltaic cells (PV) in order to obtain a constant power output irrespective of the intensity of solar radiation with low installation and maintenance cost.The proposed model is developed with the help of MATLAB/Simulink.

Keywords: Ćuk converter, PWM Technology, impedance source inverter, VFD technology.

1. INTRODUCTION

Solar and wind has emerged as the two major sources of energy in the present decades. This is because of its large availability and they are more economic sources than the sources currently available. As the availability of these sources will not remain the same and varies with time additional storage devices is to be installed to get the desired output. One of the major applications of solar energy is that it can be used for water pumping that is for small scale irrigation. In solar water pumping system a number of PV cells are used in order to get the desired output to run a motor. These PV cells may consume a lot of space which intern increases the installation cost .As the intensity of solar radiation will not remain constant , a battery source is to be installed which will again increases the cost.In this project, it is aimed to produce a water pumping system which will produce a constant output whatever be the input. The system must be free from a battery source which in turn saves 60% of the installation cost and should be sufficient to drive a motor for small scale irrigation purpose used.

One of the major components installed in this project is the photovoltaic cell (PV cells) which will convert the solar radiation into electrical DC output. The DC electrical energy obtained may be the required output otherwise the output from the PV cells is raised by means of Ćuk converter. The output of the Ćuk converter is then passed into an impedance source network in order to stabilize the electrical output and to avoid ripples in it. It is fed into a three phase converter so that three phase constant AC output will be obtained from the system which is independent of the intensity of solar radiation. A complete simulation model by using MATLAB or SIMULINK ispresented in this paper and also the complete hardware is provided.

2. MODELLING OF SOLAR WATER PUMPING SYSTEM

A. PV CELLS

Solar photovoltaic cells are used in order to convert the solar radiation or energy into electrical energy. These cells are composed of different layers of semiconductor materials such as silicon. When solar radiation incident on these cells, photons of the radiations are absorbed within these semiconductor material. These will intern excite the electrons, causing electrons to flow and creating current which will flow only in one direction i.e., direct current.

Fig.1.PV Panel

Here we are using a 12 kW panel under 1000 w/m^2 intensity of light.

B. ĆUK CONVERTER

It is a type of DC-DC converter that has an output voltage magnitude either greater than or less than input voltage. There are variations in Ćuk converter. It enables the energy flow bidirectional by adding a diode and a switch. The basic circuit of a Ćuk converter is shown below.

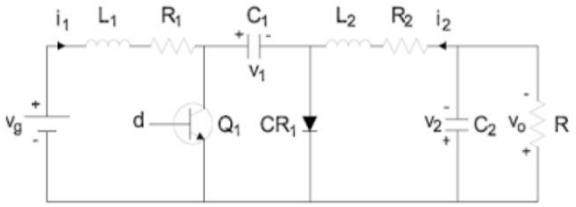

Fig.2.Ćukconverter

It consists of an additional inductor and a capacitor. The circuit is like the buck and boost converter.

C. IMPEDANCE SOURCE NETWORK

An impedance source network is a type of power converters that convert direct current into alternating

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current. It functions as a buck-boost converter without using DC-DC converter bridge. It can be used for a variety of applications such as DC-DC conversion, DC-AC conversion, AC-AC conversion and AC-DC conversion. They can be classified depending on different basics. Based on their structure it is classified into single phase inverter, three phase inverter.

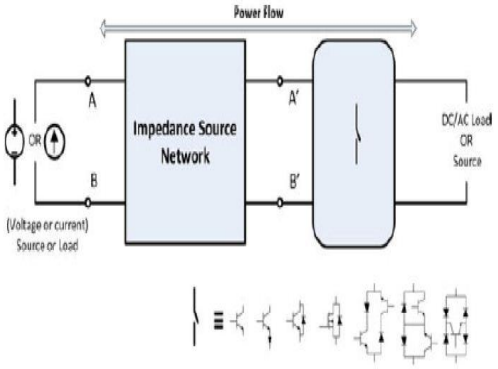


Fig.3.General configuration of impedance source network

Based on the type of input inverters are classified into (1) Voltage-source inverter and (2) Current-source inverter. In voltage-source inverter a constant voltage source will acts as an input source to the inverter bridge. This source is obtained by adding a large capacitor across DC source. In current-source inverter a constant current source will acts as an input device and this is obtained by adding a large inductor across the DC source.

Even though they can be used for various applications, there are many disadvantages also. They can either acts as a buck or boost converter at a time. Thus the output will be either larger or smaller than the input voltage. Both of them possess low reliability and are vulnerable to EMI noise so that they can get damaged easily. The switching device of both of the inverters is not interchangeable. To overcome these difficulties impedance source inverters are used. In impedance source network the source can be either voltage source or current source. It works as a buck-boost inverter.

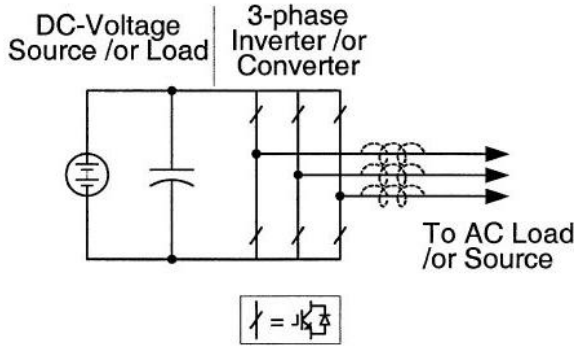


Fig.4.Voltage-Source Inverter

In this project the impedance source network performs multiple functions. One of such application is it avoids or filter the ripples which is in the DC output so that the output of the impedance source network will be ripple free.

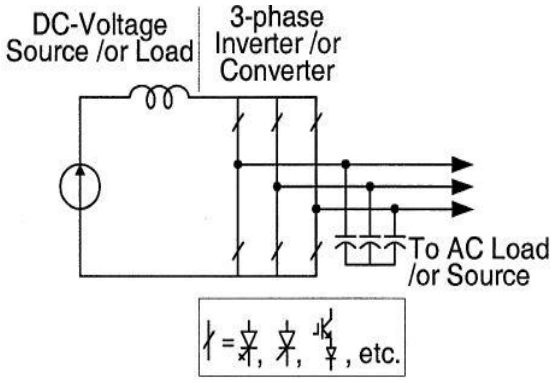
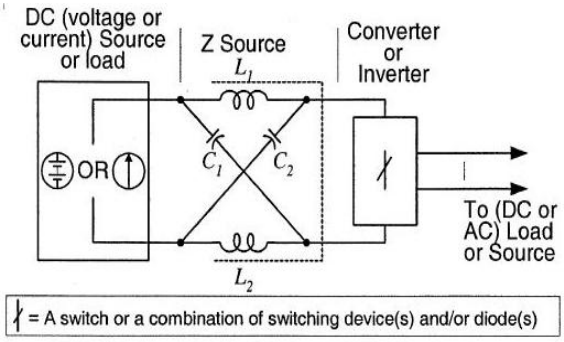


Fig.5.Current-Source Inverter

Another function is to stabilize the output. This has to be done because the output should remain constant and stable whatever be the input at any time which is the ultimate aim of this project.



D. THREE PHASE CONVERTER

A three phase converter is a device which converts single phase power to three phase and vice versa. These are used where three phase conversion is not directly available or its cost is too high in a remote area. Three phase motors may operate by an unbalanced load which is not heavily loaded. A single phase motor can itself drive a three phase generator which will produce a high quality output consuming a large amount of money. Several methods exit to run a three phase motor by a single phase supply[7]. They are electronic means of creating a three phase power, a digital phase converter and rotary phase converters etc.

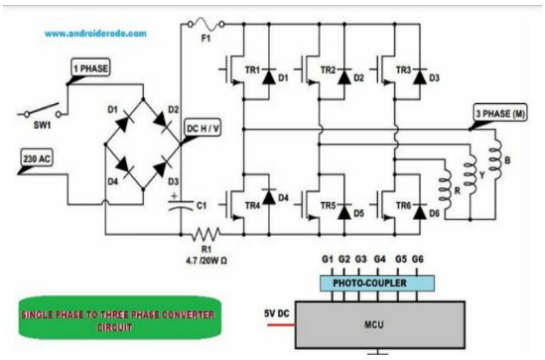


Fig. 7.Single phase to three phase converter

E. VFD TECHNOLOGY

A variable frequency drive is a device i.e. a type of adjustable speed drives used for controlling the motor

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speed and torque of an AC motor by adjusting the voltage and the frequency.

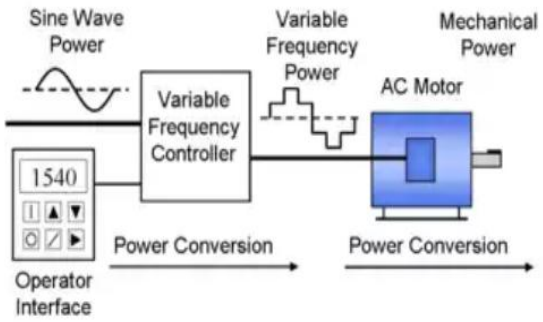

Fig.8.VFD system

A variable-frequency drive consisting of three main sub-systems: AC motor, main drive controller and a drive.

a. AC Motor
An AC motor used is usually a three-phase induction motor. Instead of three phase, single phase motors can be also used. Motors that are designed for constant speed operation are also suited to use as AC motors.

b. Controller
They can be configurated as phase converter having single phase converter input and three-phase inverter output.

F. PULSE-WIDTH MODULATION
Pulse-width modulation or Pulse-duration modulation is a modulation technique to encode a message into pulsating signal. The main advantage of PWM technique is that the power loss in switching devices is very low.

The main advantages of PWM technique is
(1) Fast switching is possible.
(2) Less heat is dissipated.
(3) Low power transistors can be used for switching
(4) Resist to noise.

The main disadvantages are
(1) Cost
(2) Complexity
(3) Radio frequency interference
(4) Voltage spikes
(5) Electromagnetic noise

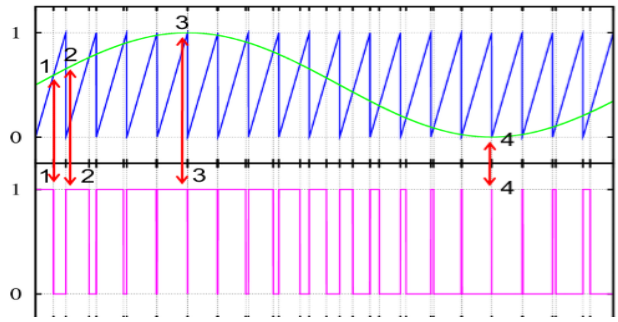

Fig.9. Pulse width modulation

3. OVERALL PROCESS

The overall processes that take place in this solar water pumping system is that the solar radiations will incident on the solar panels and photons will get emitted. These that the ripples in the current will get eliminated and the current will be a stabilized one. This stabilized DC current is then passed through a three phase converter so that the output is converted into three phase AC output which will be three phase 415 volt AC output.

This is explained in both the circuit diagram photons are absorbed by the PV cells and the electrons will get excited. Thus there will be a flow of electrons which inturns call the current flow. This will be DC current.

This current is then allowed to pass through a Ćuk converter so that the voltage will get raised in order to get the desired output current. This current is then allowed to pass through the impedance source network so and in the block diagram shown. In this figure the MOSFET will act as a switch so that when a gate pulse is applied it will get on and the circuit will get worked.

In the circuit six IGBT s are connected as three phase converter so that two IGBT s are grouped each other so that a complete sin wave will be obtained. The gate pulse applied will be 180 ^{0} phase shift from each other so that a complete three phase AC output will be obtained from the circuit. Here VFD technology is introduced in order to obtain a synchronous speed and required torque by adjusting the voltage as well as frequency.

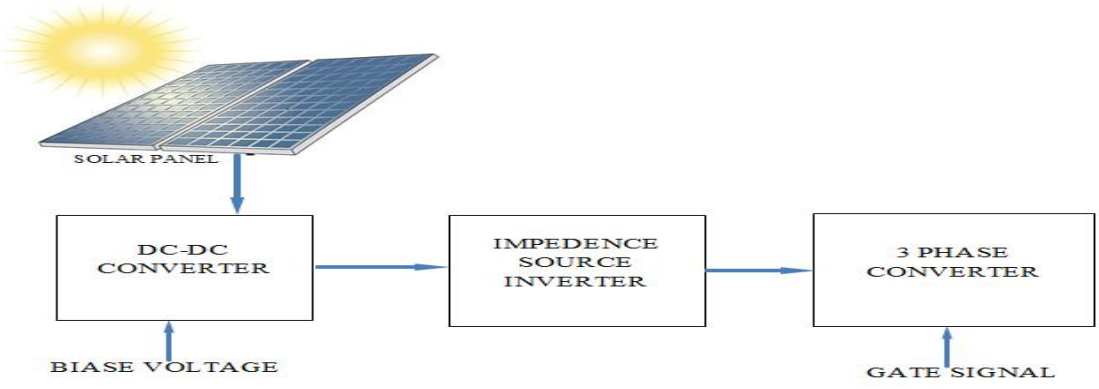

Fig.10.Block diagram

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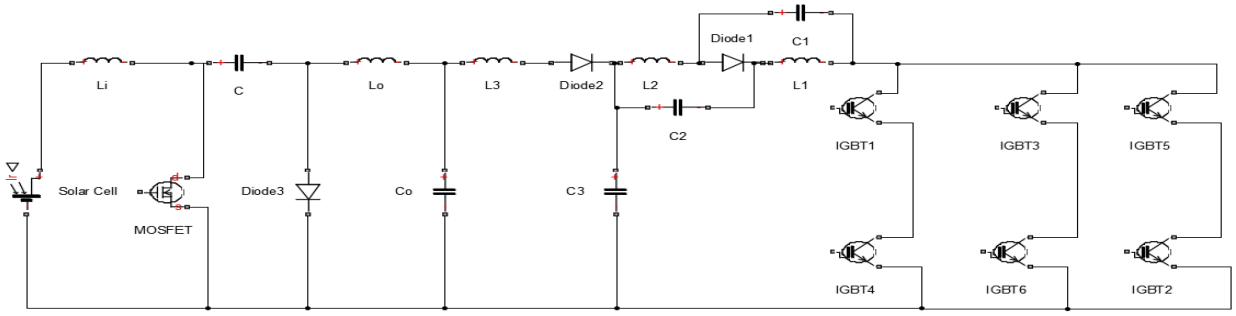

Fig.11. Circuit diagram

4. SIMULINK MODEL

The complete simulink model obtained is shown below

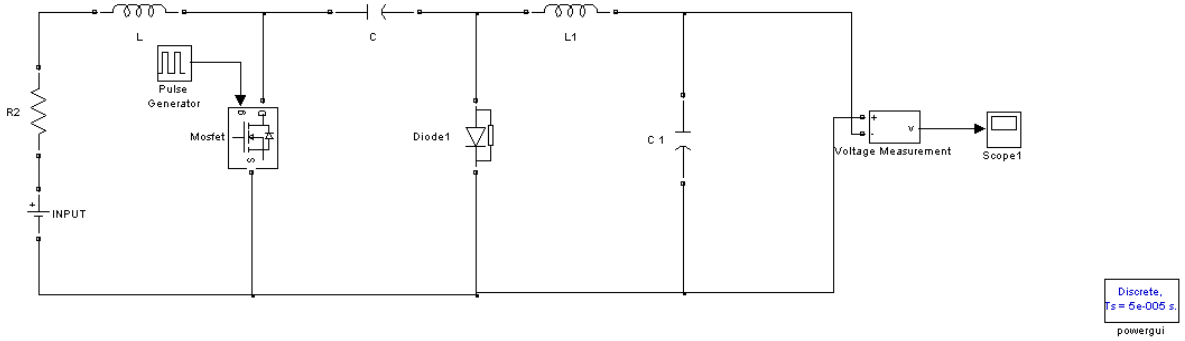

Fig.12.Simulink model of cuk converter

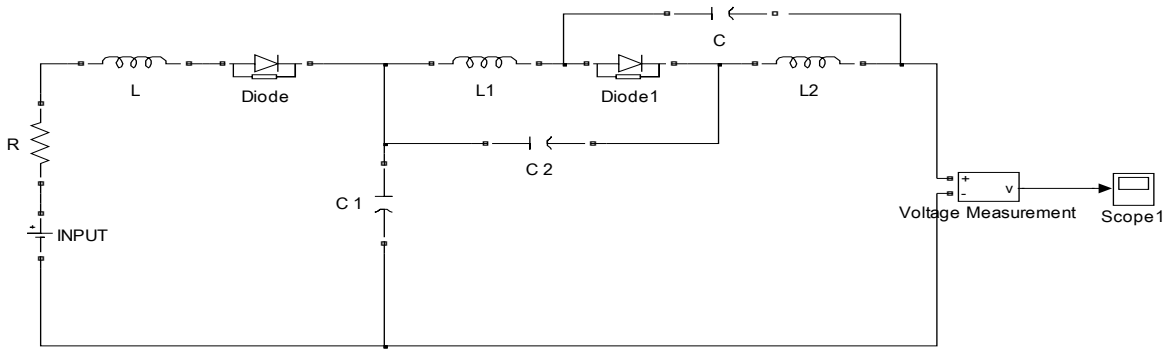

Fig.13.Simulink model of impedance source inverter

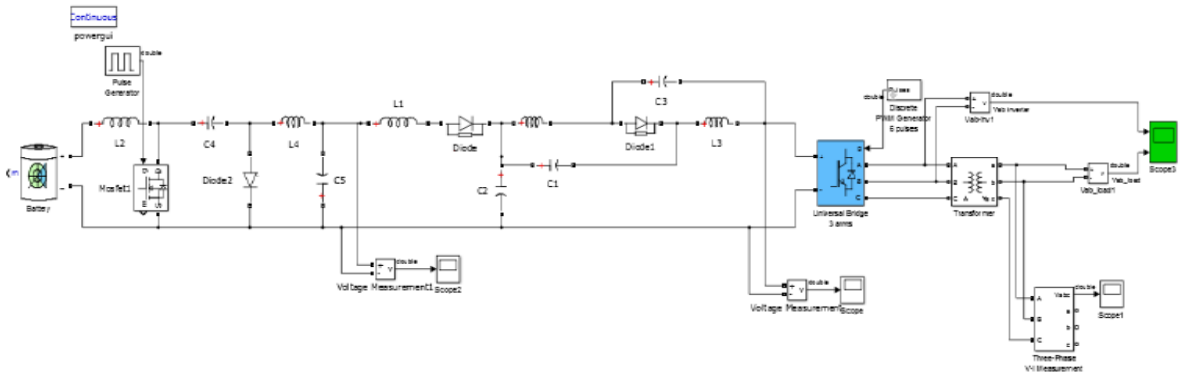

Fig.14.Complete simulation model

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5. OVERALL SIMULATION OUTPUT

The overall circuit is simulated by integrating each part of the circuit i.e. PV panel, cuk converter, impedance source inverter, three phase converter etc. to verify the output i.e. to get a constant three phase AC supply of 415 V.

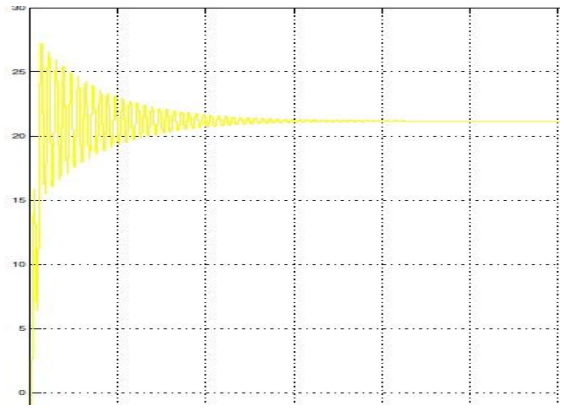

Fig.15.output of cuk converter

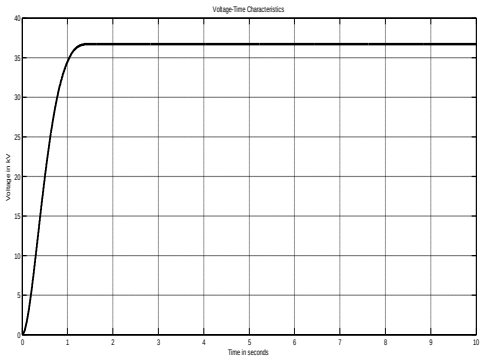

Fig.16.Output graph of impedance source inverter

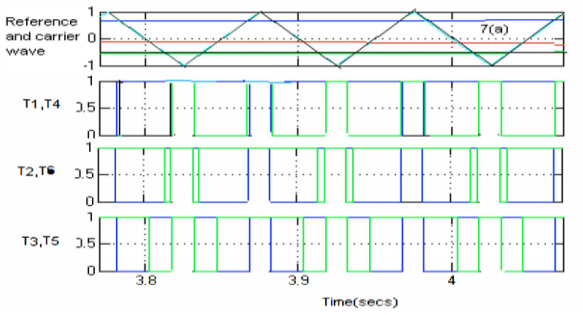

Fig.17.Firing pulses impedance source inverter

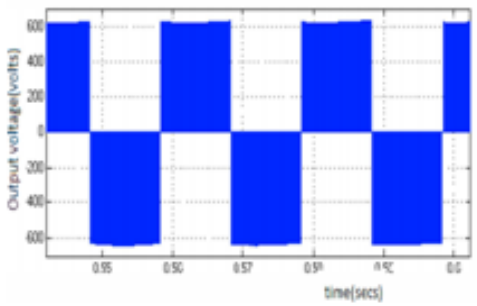

Fig.18.Voltage profile of impedance source inverter

6. CONCLUSION

This paper has presented a complete review of a solar pumping system which works with solar radiation but independent of the intensity of solar radiation. Thus the number of solar panels required as well as the area required can be reduced. This pumping system doesn't need any storage devices such as battery source. Since there is no battery source the installation cost can be reduced and also the maintenance cost. It can be used for pumping at a height of 200 meters. Also in this system no-load cut off is also possible. i.e. the system will get shutdown if there is no output in the system.

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